BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 09080

SUBJECT: An Improved Thruster Firing Sequence for Spin-up of Skylab B for Artificial Gravity - Case 620

DATE: September 30, 1970

FROM: L. E. Voelker

ABSTRACT

The Service Module Reaction Control System thrusters, when operated in a pulsed mode, can spin up Skylab B for an artificial gravity experiment. A recently developed thruster firing procedure that results in minimum fuel consumption specifies the thrusters to be fired and the total firing time for each, but does not specify the firing sequence. A sequence that minimizes the absolute value of the angular impulse applied about axes other than the correct one causes the Skylab to wobble somewhat and the angular momentum vector to deviate slightly from its desired orientation. A firing sequence that is symmetric in time about specific points reduces the wobble by a factor of five and the angular momentum deviation by an order of magnitude over the previously studied non-symmetric sequence. This symmetric firing sequence is therefore superior for the spin-up maneuver.

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MEMORANDUM FOR FILE

Reference 1 describes a procedure for applying a desired angular impulse to Skylab using minimum Service Module Reaction Control System(RCS) fuel. The procedure specifies the proper RCS thrusters to be fired and the total firing time of each. For an artificial gravity experiment on Skylab B, the angular impulse for spin-up would be applied about the axis of maximum moment of inertia using the RCS thrusters in a pulsed mode. A basic period P, in which all the selected thrusters are to be fired, is found by dividing the spin-up time into N increments of equal size. The total firing times of the thrusters, obtained by the procedure of Reference 1, are also divided into N equal increments so that each thruster fires for a fixed portion of each basic period. (Note that this division of the total firing times for all thrusters into the same N increments is not necessarily the only technique that will provide acceptable dynamic results.) The smallest thruster firing time should be of the order of one second to achieve maximum specific impulse. The largest firing time should not be so large as to introduce appreciable components of angular velocity about axes perpendicular to the axis of maximum moment of inertia. These restrictions guide the choice of N (or P), but do not aid in selecting the sequence of firings within the basic period P.

In Reference 2, the dynamics of spin-up are studied using a thruster firing sequence that minimizes the absolute value of the components of angular impulse about axes other than the axis of maximum moment of inertia. After spin-up to 4 rpm, the wobble angle, defined as the angle between the angular velocity vector and the axis of maximum moment of inertia, has a maximum value of about 0.2 degrees. Also, the angular momentum vector deviates from the desired orientation along the sun line by about 1.8 degrees. Investigation of the dynamics during the maneuver indicates that this repetitive firing sequence causes a buildup in wobble angle and momentum vector deviation at the end of each basic period. Reversing the sequence causes the reverse effects. Thus, alternating the original sequence and the reverse sequence should serve to reduce wobble and momentum vector motion. But alternating these sequences is, in effect, a new symmetric sequence with a basic period of 2P. A symmetric firing sequence with the mid-point of thruster firing occurring at the mid-point of the basic period should give even better results because deviations are given only half the time to develop, yet the minimum firing time remains the same.

This symmetric firing sequence was used in a simulation to spin-up Skylab B and the results compared to those of Reference 2. The comparison was done for the case where the location of the axis of maximum moment of inertia is known precisely. After spin-up using this centered symmetric sequence the maximum wobble angle is about 0.04 degrees, about 1/5 the previous result. The angular momentum vector deviates less than 0.2 degrees from the desired orientation on the sun-line, a reduction of approximately one order of magnitude. The symmetric firing sequence is therefore superior to the sequence used in Reference 2, and is certainly acceptable for the minimum fuel spin-up of Skylab B for an artificial gravity experiment.

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1022-LEV-mef

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Attachment
References

REFERENCES

1. Hough, W. W. and Nelson, L. D., "Minimization of SM RCS Fuel for Skylab Attitude Maneuvers," TM-70-1022-13, August 1970, Bellcomm, Inc., Washington, D.C.

2. Voelker, L. E., "Spin-up of Skylab B for Artificial Gravity," TM-70-1022-14, September 1970, Bellcomm, Inc., Washington, D.C.

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